MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2016/2017**

## EMF4076 –ELECTROMAGNETIC INTERFERENCE
(EE, TE& MCE)

9th MARCH 2017
9:00 A.M. – 11:00 A.M.
(2 Hours)

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**INSTRUCTIONS TO STUDENTS**

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) State the electromagnetic interference (EMI) mechanism for the following scenario: A car manufacturer plans to introduce a mid-size executive sedan with 1.6 litre turbo-charge petrol engine. To further reduce waste gas emissions and improves fuel economy, the design engineers decided to implement engine start-stop system in the ECU (engine control unit) software. The ECU shuts down the engine whenever the engine is idling at traffic light or during traffic jam. The ECU automatically restart the engine when the car is ready to move. During initial test drive, it has been discovered that the car infotainment system sometimes mal-function whenever the engine is restarting. An example is the radio sometimes tunes to another station when the engine restarts during stop-and-go traffic.

Also identify the interference source, coupling path and susceptible receiver, and whether it is an intra or inter-systems EMI.
*Note: the petrol engine has an electric motor/alternator, which draw current from the battery and turns the engine's crank-shaft during engine start process.*

[6 marks]

(b) Figure Q1(b) shows the cross section view of a three conductor cable. The conductors are protected by PTFE (Polytetrafluoroethylene) dielectric, with dielectric constant, $\varepsilon_r = 2.1$ and relative permeability, $\mu_r = 1.0$.

(i) Determine the lumped LC elements for the cable and sketch the equivalent circuit if the length of the cable is 20 cm. *Hint: you may ignore the effect of GND plane for $C_{12}$ calculation.*

(ii) Based on the equivalent circuit, state whether inductive or capacitive coupling is more severe and give reasons for your answer.

[11 + 3 marks]

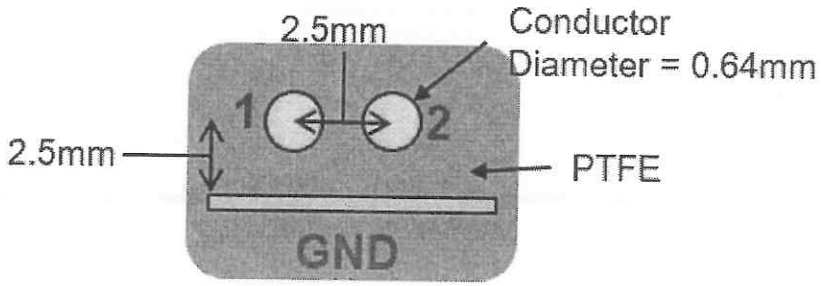
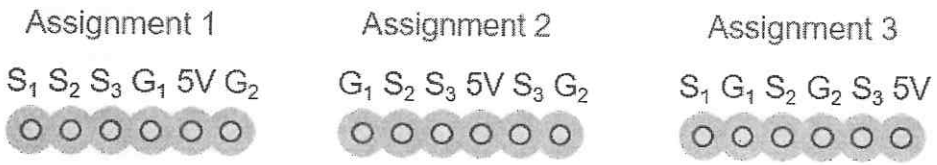



Figure Q1(b)

**Continued . . .**

(c) Figure Q1(c) shows three cross section views of a six conductors (also known as six cores) cable which carries digital signals $S_1$ to $S_3$, ground (GND) for return current and a 5V supply. The cable is used to connect two electronic circuit boards, which transmit digital data between each other. Based on your understanding of coupling mechanisms, choose the best conductor assignment in terms of minimizing the coupling noise level. Note that $GND_1$ and $GND_2$ are physically connected in the circuit boards. Support your answer with a brief explanation.

[5 marks]




$S_1$ – Signal 1
$S_2$ – Signal 2
$S_3$ – Signal 3
$G_1$ – GND 1
$G_2$ – GND 2
5V – 5V supply

Figure Q1(c)

Question 2

(a) A single-point ground system is shown in Figure Q2(a).

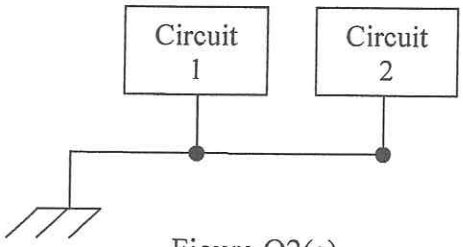



Figure Q2(a)

(i) What is the type of single-point ground system shown in Figure Q2(a)? State the advantage of this system.

[3 marks]

(ii) Explain the effect of common impedance coupling to the system in (i).

[3 marks]

(iii) Suggest and draw an improved ground layout to solve the effect in (ii).

[3 marks]

**Continued . . .**

(b) Two integrated circuits (ICs) are connected to a power distribution bus and the Thevenin equivalent circuit is shown in Figure Q2(b).

(i) Describe the main reason to include the decoupling capacitor, $C_d$ into the power distribution bus.

[4 marks]

(ii) What is the purpose of putting the series resistance, $R_{d1}$ and $R_{d2}$, to each load?

[3 marks]

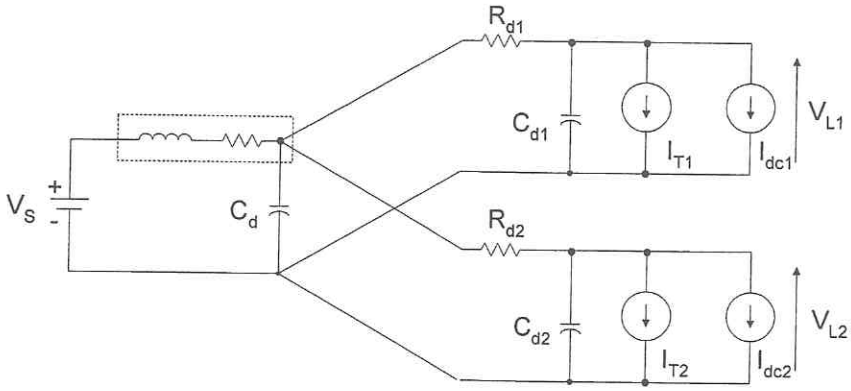



Figure Q2(b)

(c) A load with the load current, $I_L$, is connected to the end of a power distribution bus, and the Thevenin equivalent circuit is shown in Figure Q2(c). The decoupling capacitor, $C_d$ is used to prevent load voltage, $V_L$ from decreasing below the minimum acceptable supply voltage, $V_s$. The length of the bus is 30 cm and the propagation velocity is 40% of the speed of light. Assuming the characteristic impedance, $Z_o$ equals to 50 ohm, and transient current, $I_T$ is a step function that equals to 20 mA.

(i) Determine the maximum change in $V_L$ for $C_d$= 0.01 μF and $C_d$= 0.

[6 marks]

(ii) What is the required value for $C_d$ in order to limit the change in $V_L$ to 0.02 V?

[3 marks]

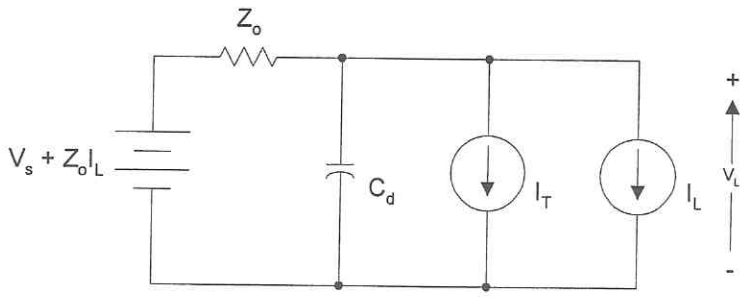



Figure Q2(c)

**Continued . . .**

Question 3

(a) Define skin depth and its relationship with frequency and material properties of shielded enclosure.

[4 marks]

(b) The expressions for electric-fields and magnetic-fields of a small current loop of area $A$ in the x-y plane and excited by a time varying current $I_o e^{j\omega t}$ is given by:

$$H_S = \frac{jkI_o A}{4\pi}\left[2\left(\frac{1}{r^2}+\frac{1}{jkr^3}\right)\cos\theta\ \hat{a}_r + \left(\frac{jk}{r}+\frac{1}{r^2}+\frac{1}{jkr^3}\right)\sin\theta\ \hat{a}_\theta\right]e^{-jkr}$$

$$E_S = -\eta\frac{jkI_o A}{4\pi}\left[\left(\frac{jk}{r}+\frac{1}{r^2}\right)\sin\theta\ \hat{a}_\phi\right]e^{-jkr}$$

where $\eta$ = intrinsic wave impedance, $I_0$ = current amplitude, $k$ = phase constant
$r$ = distant from the source, $l$ = length of dipole

For near-field and far-field regions,

(i) Derive the simplified equations for the electric-fields and magnetic fields.

[8 marks]

(ii) Deduce the wave impedance at both regions.

[3 marks]

(c) Figure Q3(c) illustrates a signal source connected to the load resistor using a pair of wire where a dedicated ground wire close to a signal wire will force most of the signal current to return to the source through the dedicated ground wire. The mutual inductance, $M$, between the two wires increase when they are placed closer together. A common ground-wire exists in the electronics system. Calculate the percentage of return path current diverted through the common ground for values of $M$ =199 nH (close spacing), $M$ = 64 nH (moderate spacing) and $M$ = 1 nH (wide spacing).

[10 marks]

**Continued . . .**

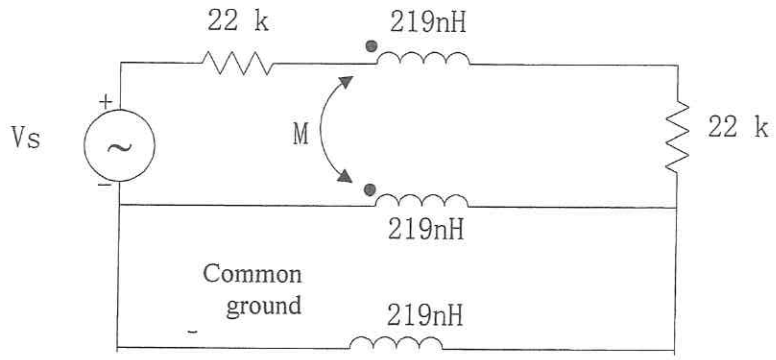



Figure Q3(c)

Question 4

(a) A company has developed a new 4 Terabytes portable external hard disk and would like to affix the Conformité Européene (CE) logo on their product. Briefly describe the process to obtain this logo and state the obligations of the company.

[7 marks]

(b) Figure Q4(b) shows the setup for measuring radiated EMI susceptibility of an equipment-under-test (EUT). Explain the purpose of having the absorbers in the shielded chamber. What would happen if the absorbers are absent?

[6 marks]

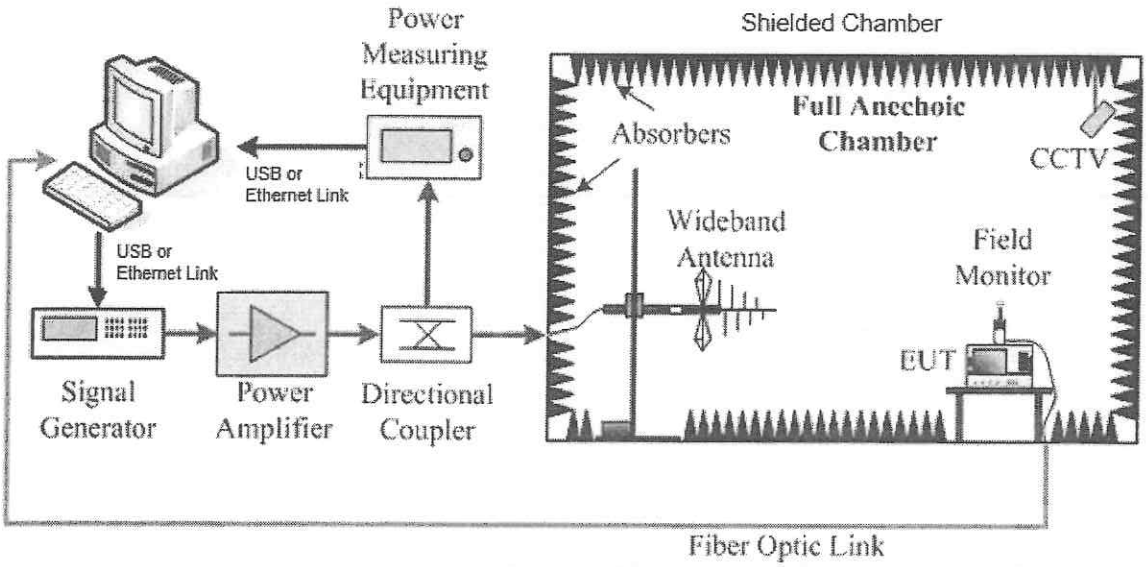



Figure Q4(b)

(c) With an aid of a relevant diagram, explain the setup and procedures for conducted emission measurement of a EUT.

[12 marks]

**End of Page**

## Appendix- Useful Formula

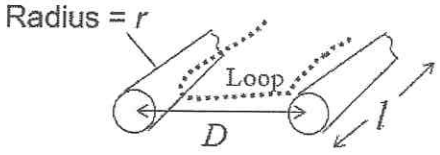
**Free-space physical constants:**

$\mu_o = 1.25664\times10^{-6}$ N/A$^2$

$\varepsilon_o = 8.85419\times10^{-12}$ F/m

**Approximate formula for inductance and capacitance:**

Radius = $r$

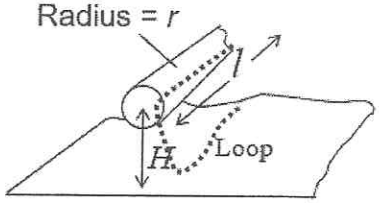



Assume $D >> r$

$$L \cong \frac{\mu l}{4\pi} + \frac{\mu l}{\pi}\ln\left(\frac{D-r}{r}\right)$$

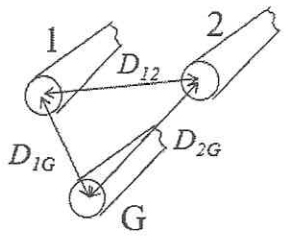
Internal inductance

Radius = $r$




Assume $H >> r$

$$L \cong \frac{\mu l}{8\pi} + \frac{\mu l}{2\pi}\ln\left(\frac{2H-r}{r}\right)$$

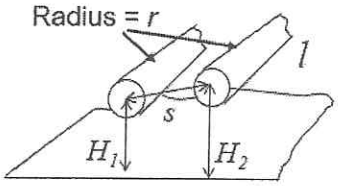



$$L_{12} \cong \frac{\mu l}{2\pi}\ln\left(\frac{D_{1G}D_{2G}}{rD_{12}}\right)$$

All conductor radius = $r$

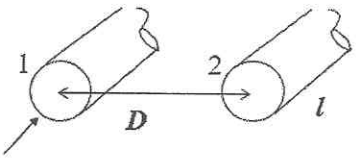
Assume $D >> r$

Radius = $r$




$$L_{12} \cong \frac{\mu l}{4\pi}\ln\left(1+4\frac{H_1H_2}{s^2}\right)$$

Assume H and s >> r



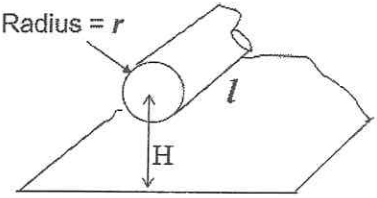

$$C = \frac{\pi\varepsilon l}{\cosh^{-1}\left(\frac{D}{2r}\right)}$$

Radius = $r$

If radius of conductor 1 & 2 are different:

$$C \cong \frac{2\pi\varepsilon l}{\cosh^{-1}\left(\frac{(D-r_1)(D-r_2)}{r_1r_2}\right)}$$

Radius = $r$




$$C = \frac{2\pi\varepsilon l}{\cosh^{-1}\left(\frac{H}{r}\right)}$$